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Takemoto et al.

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[45] **Date of Patent: *Dec. 10, 1996**

[54] **SENSOR WITH A PLURALITY OF TRANSMISSION AND RECEPTION LINES FOR DETECTING A POSITION OF A METAL OBJECT**

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[73] Assignee: **Kabushiki Kaisha Ace Denken**, Tokyo, Japan

[*] Notice: The term of this patent shall not extend beyond the expiration date of Pat. No. 5,405,143.

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[86] PCT No.: **PCT/JP91/01595**

§ 371 Date: **May 19, 1994**

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PCT Pub. Date: **May 27, 1993**

[51] **Int. Cl.**^{6} **H01F 5/00**; A63F 7/02

[52] **U.S. Cl.** .... **324/207.17**; 324/243; 324/260; 273/239; 273/121 A

[58] **Field of Search** .... 324/207.15, 207.16, 324/207.17, 232, 243, 260, 262; 273/120 A, 121 A, 121 B, 237–239; 340/540, 541, 551, 552

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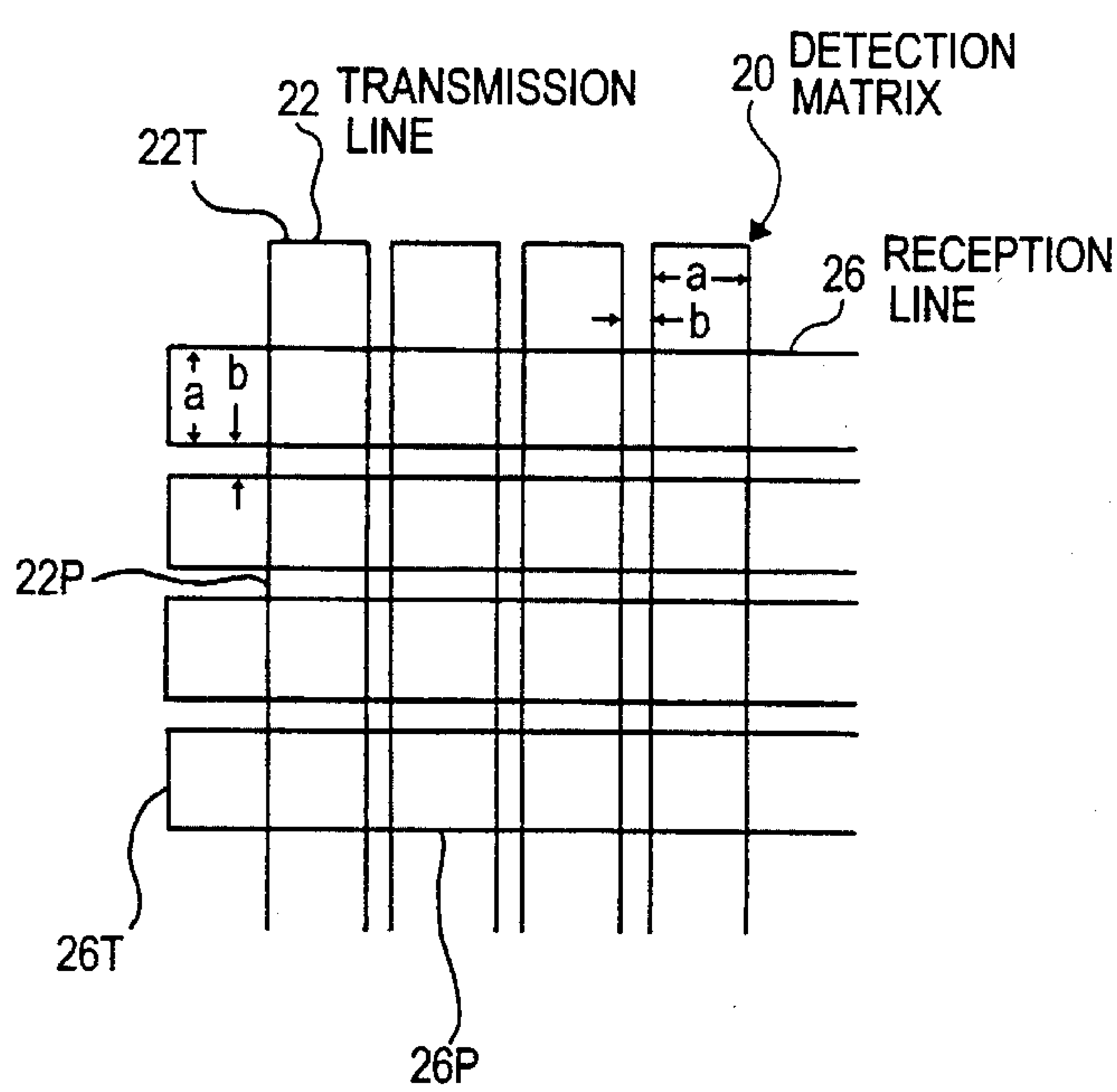
Primary Examiner—Sandra L. O'Shea
Assistant Examiner—Jay M. Patidar
Attorney, Agent, or Firm—Lowe, Price, LeBlanc & Becker

[57] **ABSTRACT**

A sensor of the invention has a plurality of transmission lines (**22**) being energized for generating a magnetic field, a board for supporting the transmission lines (**22**), a plurality of reception lines (**26**) being electro-magnetically coupled with the transmission lines (**22**) for detecting a magnetic flux change made by the approach of the metal object, and a board for supporting the reception lines (**26**). The transmission lines (**22**) and the reception lines (**26**) are made of conductive thin films formed on their respective boards having sending and returning paths. The transmission lines (**22**) and the reception lines (**26**) are laid out in a direction to cross each other with the boards between.

10 Claims, 12 Drawing Sheets



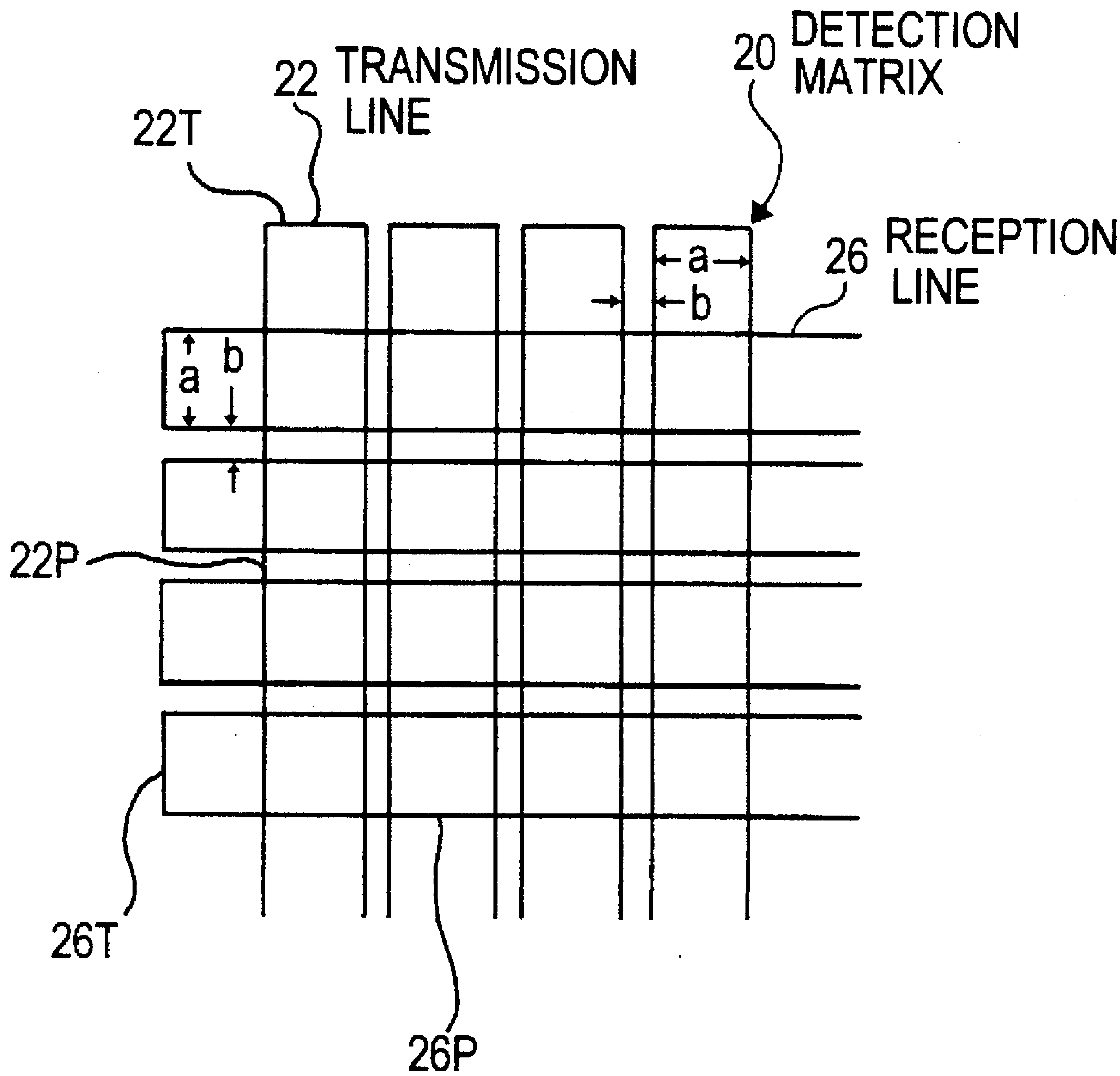

22 TRANSMISSION LINE
20 DETECTION MATRIX
22T
26 RECEPTION LINE
a
b
22P
26T
26P

FIG. 1

FIG. 2

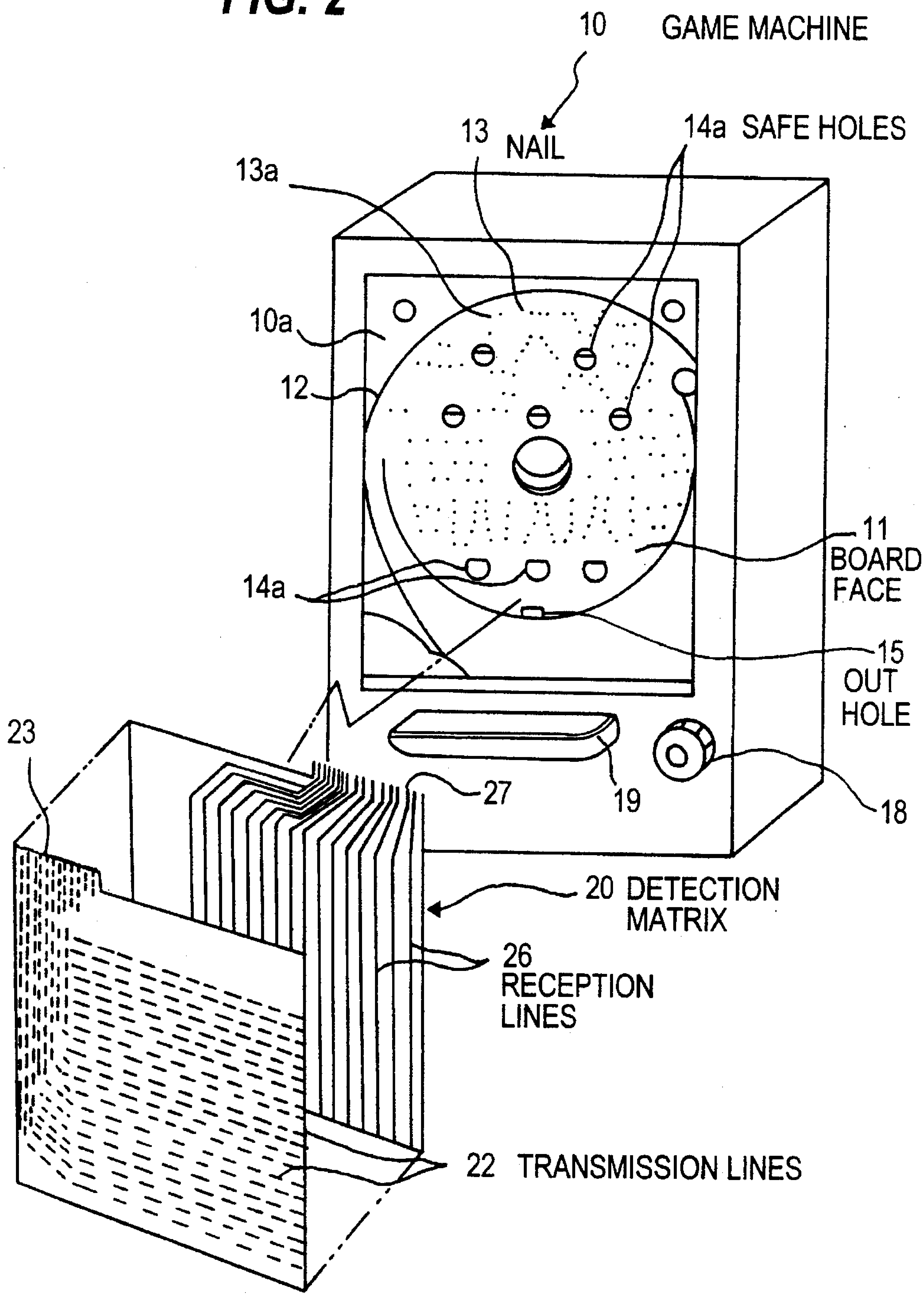
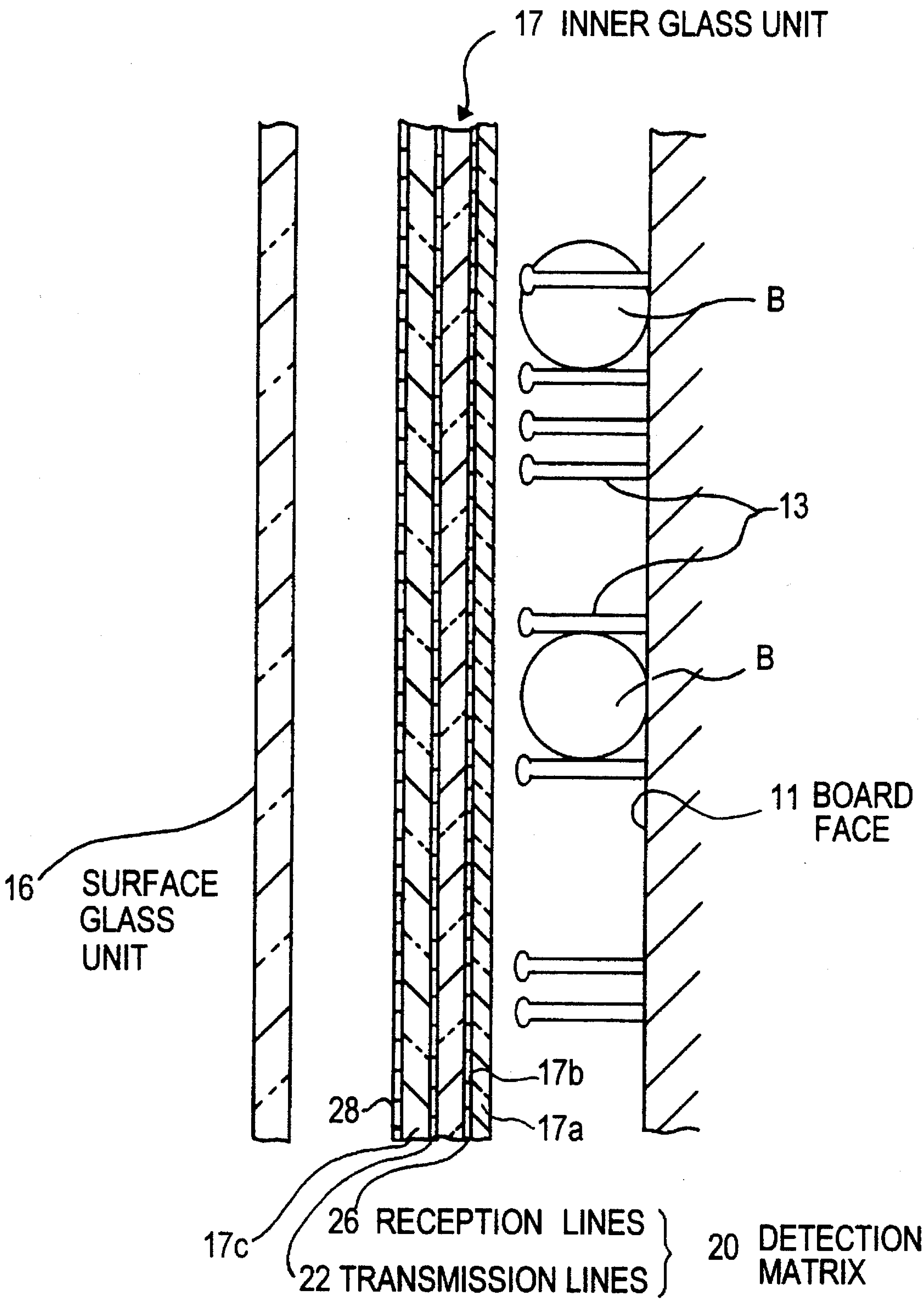

10 GAME MACHINE
13 NAIL
14a SAFE HOLES
13a
10a
12
11 BOARD FACE
14a
15 OUT HOLE
23
27
19
18
20 DETECTION MATRIX
26 RECEPTION LINES
22 TRANSMISSION LINES

FIG. 3


17 INNER GLASS UNIT
B
13
B
11 BOARD FACE
16 SURFACE GLASS UNIT
17b
28
17a
17c
26 RECEPTION LINES
22 TRANSMISSION LINES
20 DETECTION MATRIX

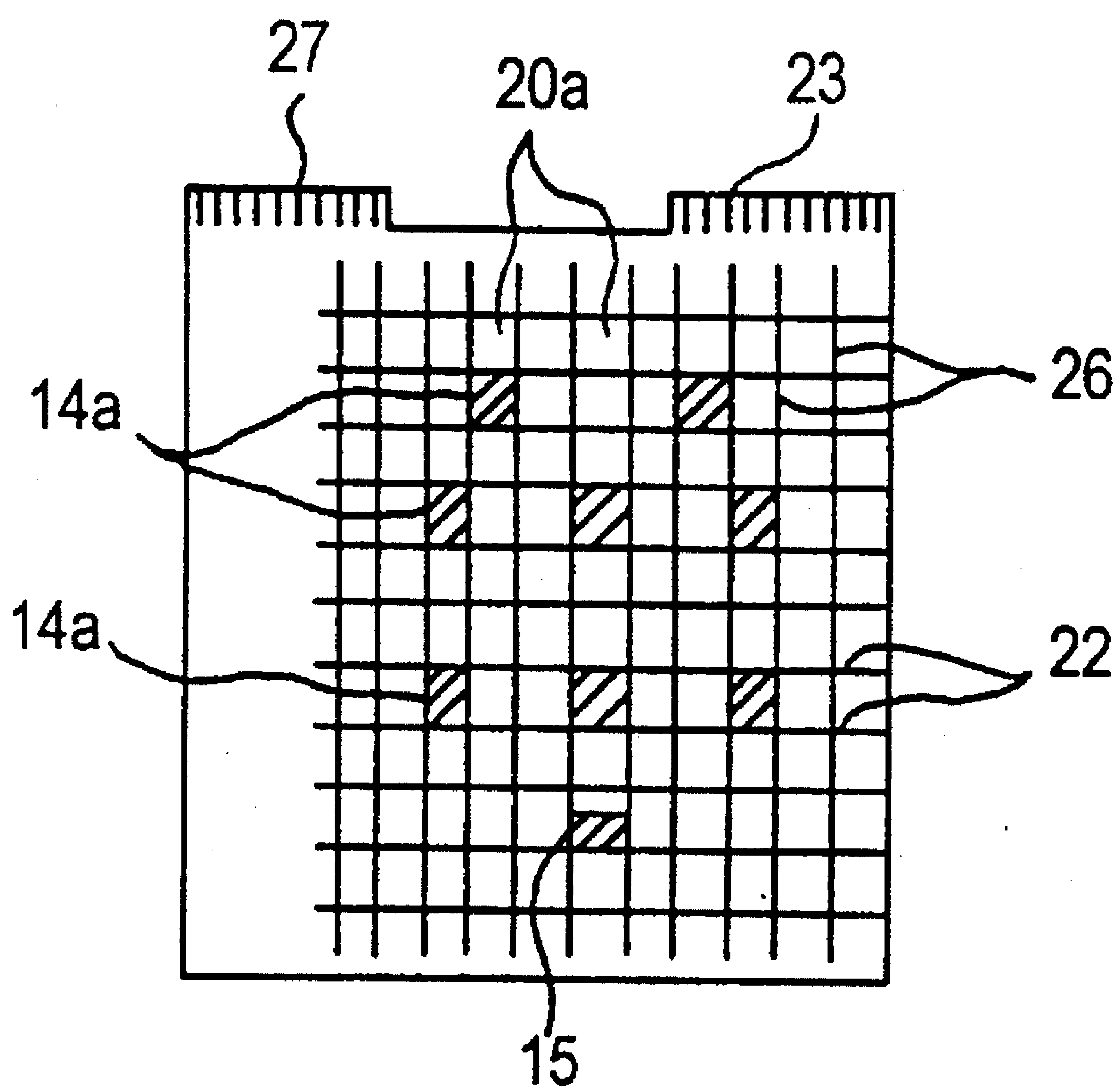


FIG. 4

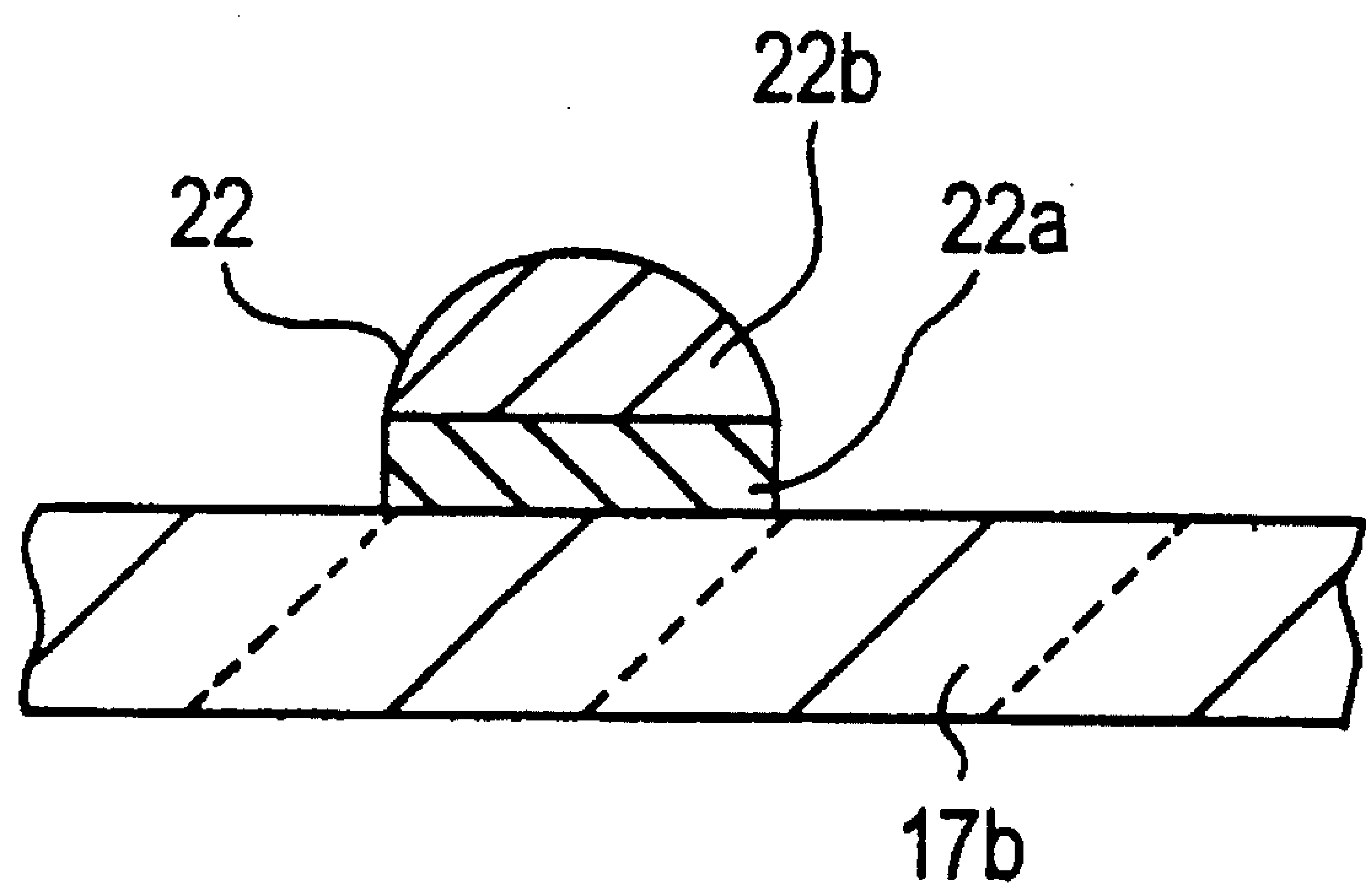
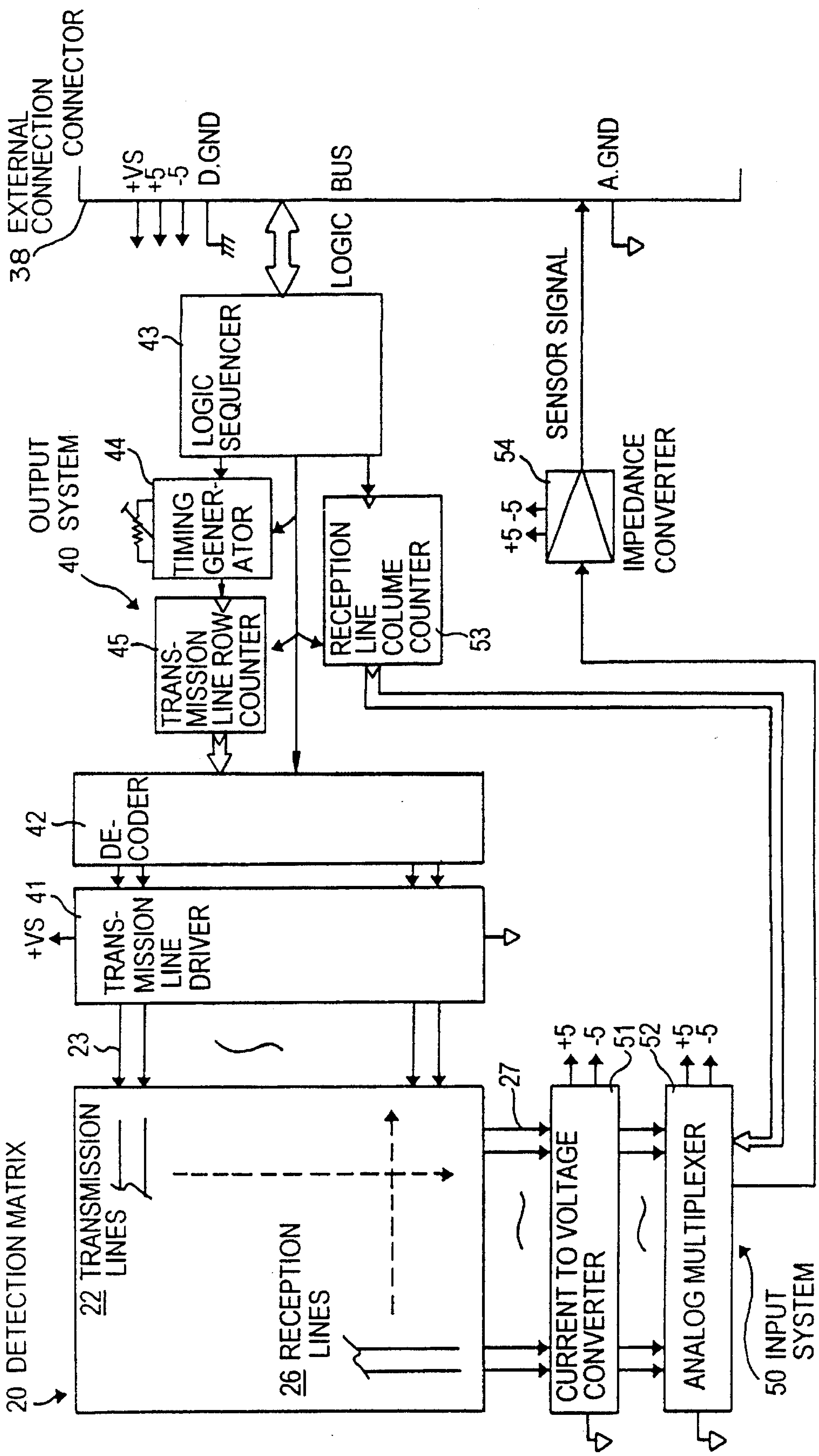


FIG. 5

FIG. 6


38 EXTERNAL CONNECTION CONNECTOR
+VS
+5
-5
D.GND
LOGIC BUS
A.GND
SENSOR SIGNAL
43 LOGIC SEQUENCER
44 TIMING GENERATOR
40 OUTPUT SYSTEM
45 TRANSMISSION LINE ROW COUNTER
RECEPTION LINE COLUME COUNTER 53
54 IMPEDANCE CONVERTER
+5 -5
42 DECODER
+VS 41 TRANSMISSION LINE DRIVER
23
20 DETECTION MATRIX
22 TRANSMISSION LINES
26 RECEPTION LINES
27
CURRENT TO VOLTAGE CONVERTER
+5 -5 51
52 +5 -5
ANALOG MULTIPLEXER
50 INPUT SYSTEM

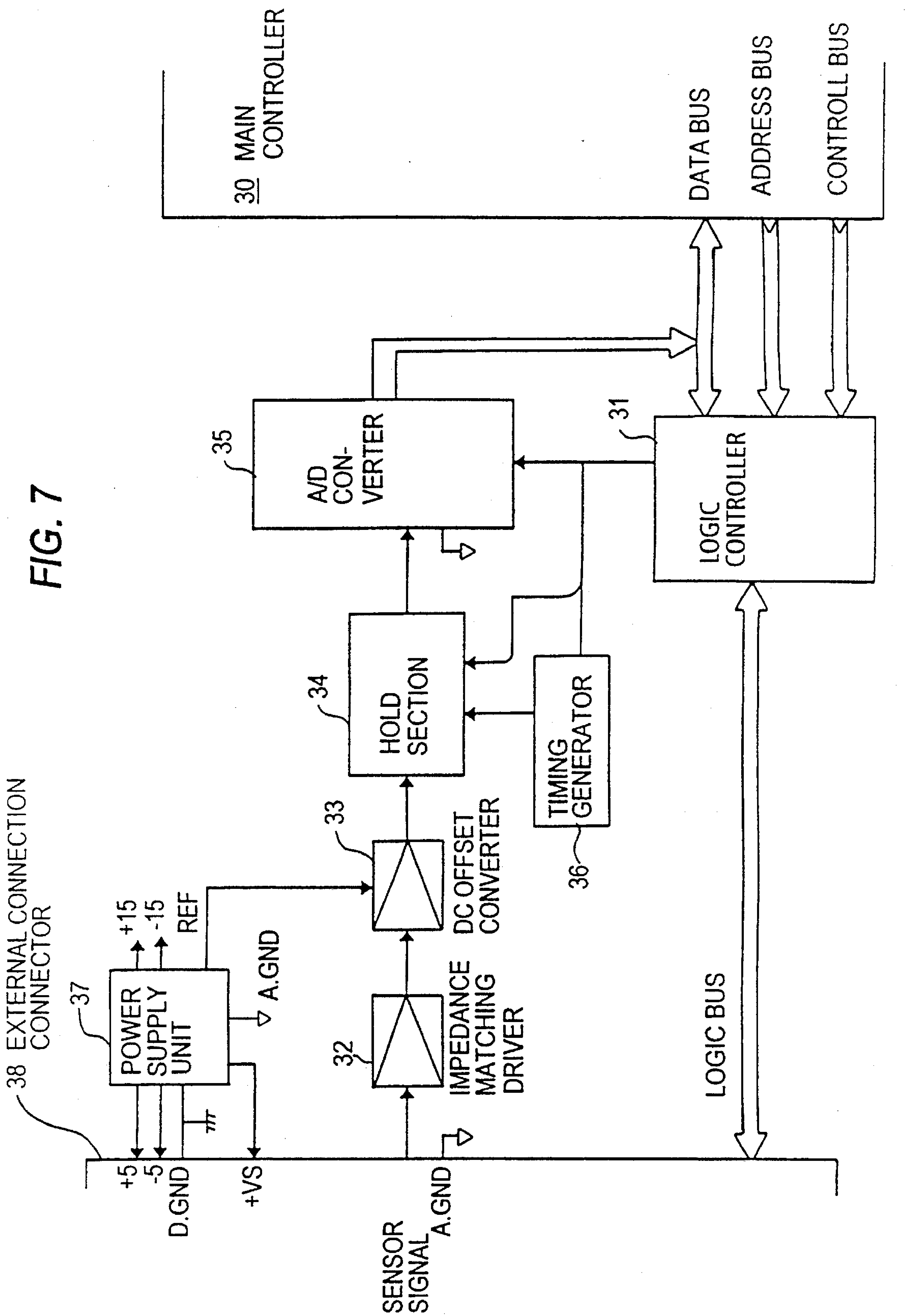

30 MAIN CONTROLLER
DATA BUS
ADDRESS BUS
CONTROLL BUS
35
A/D CON-VERTER
31
LOGIC CONTROLLER
34
HOLD SECTION
TIMING GENERATOR
36
33
DC OFFSET CONVERTER
32
IMPEDANCE MATCHING DRIVER
38 EXTERNAL CONNECTION CONNECTOR
37
POWER SUPPLY UNIT
+15
-15
REF
A.GND
+5
-5
D.GND
+VS
SENSOR SIGNAL
A.GND
LOGIC BUS

FIG. 7

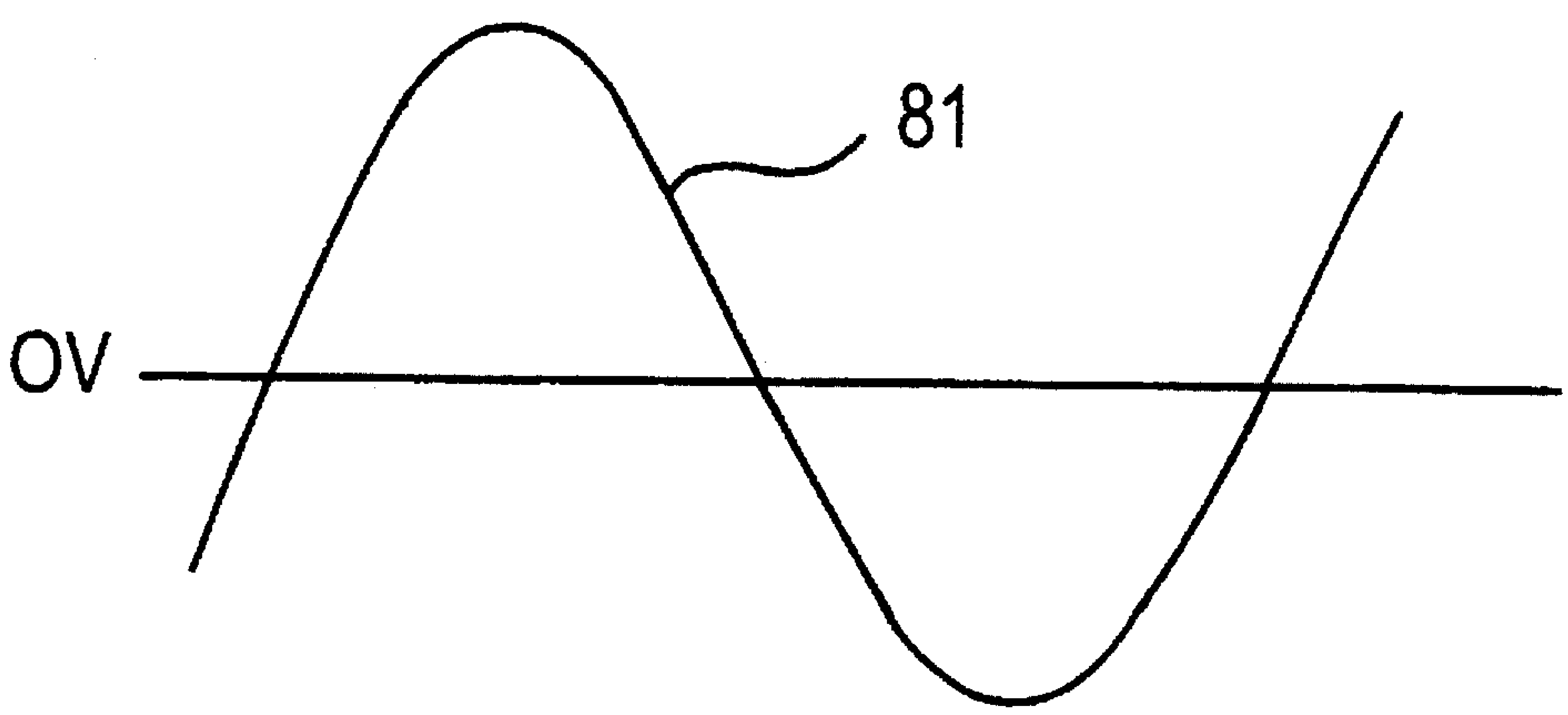


FIG. 8

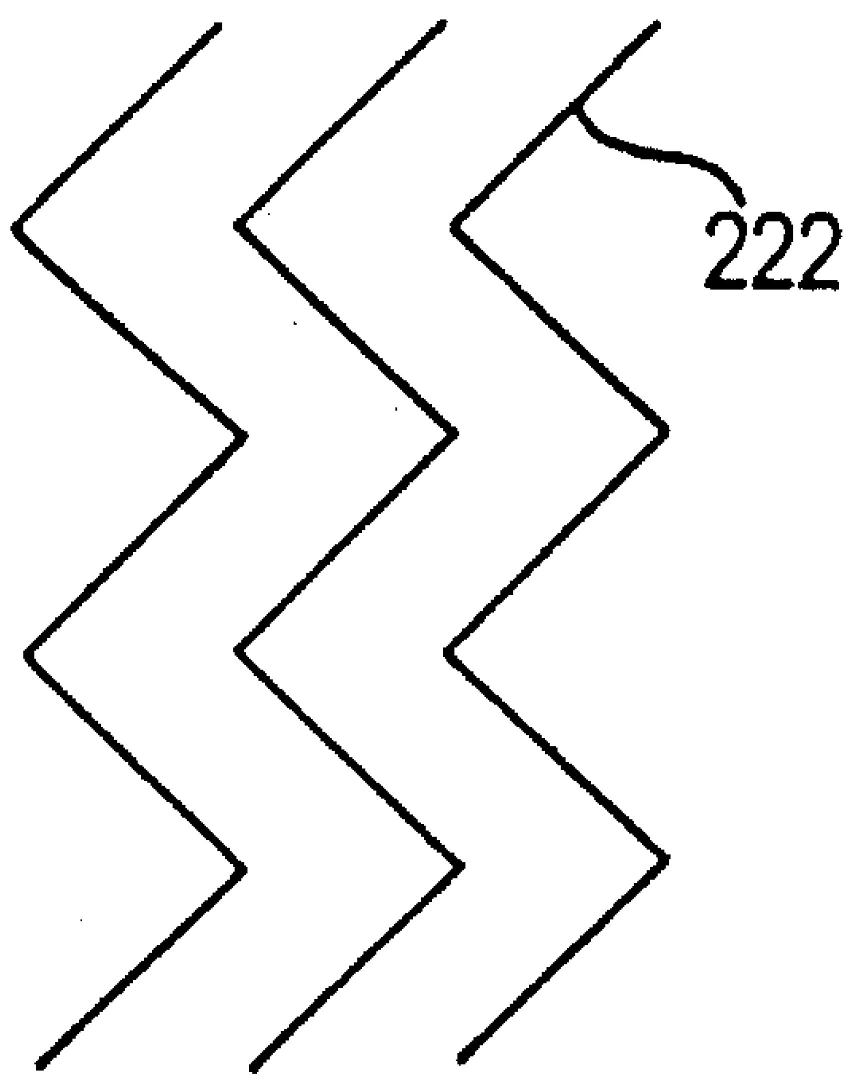


FIG. 9

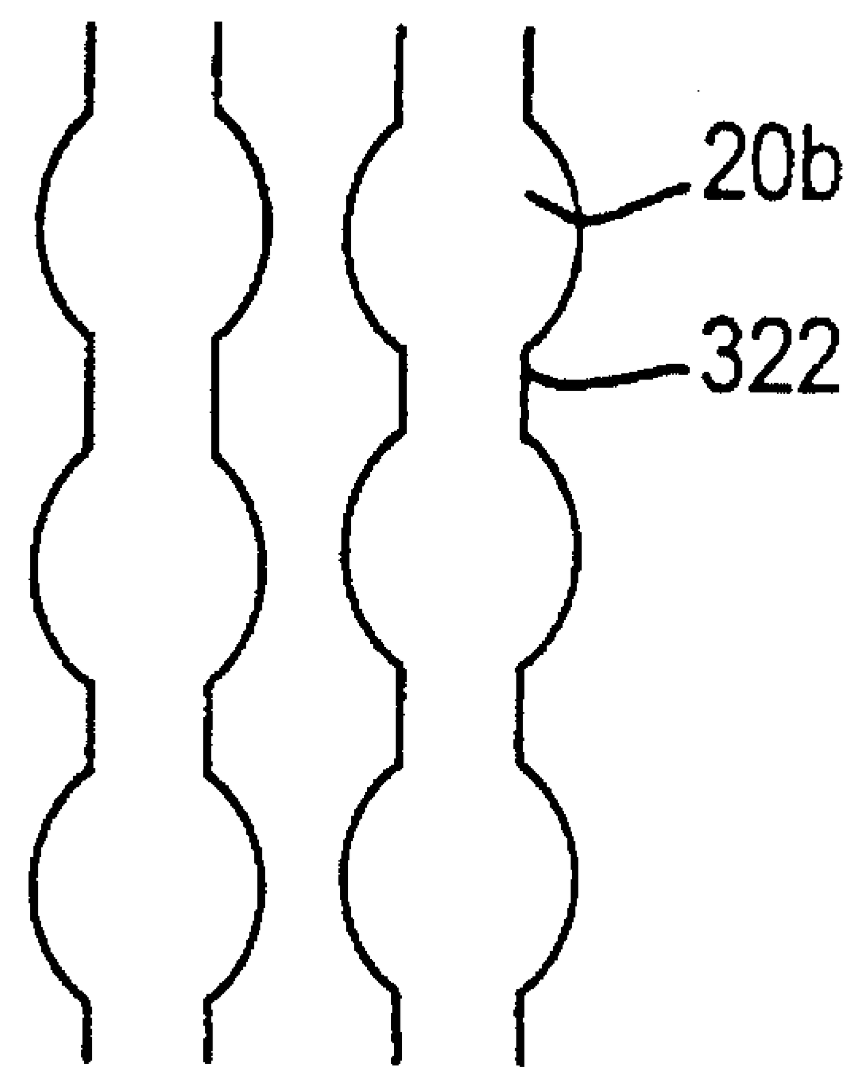


FIG. 10

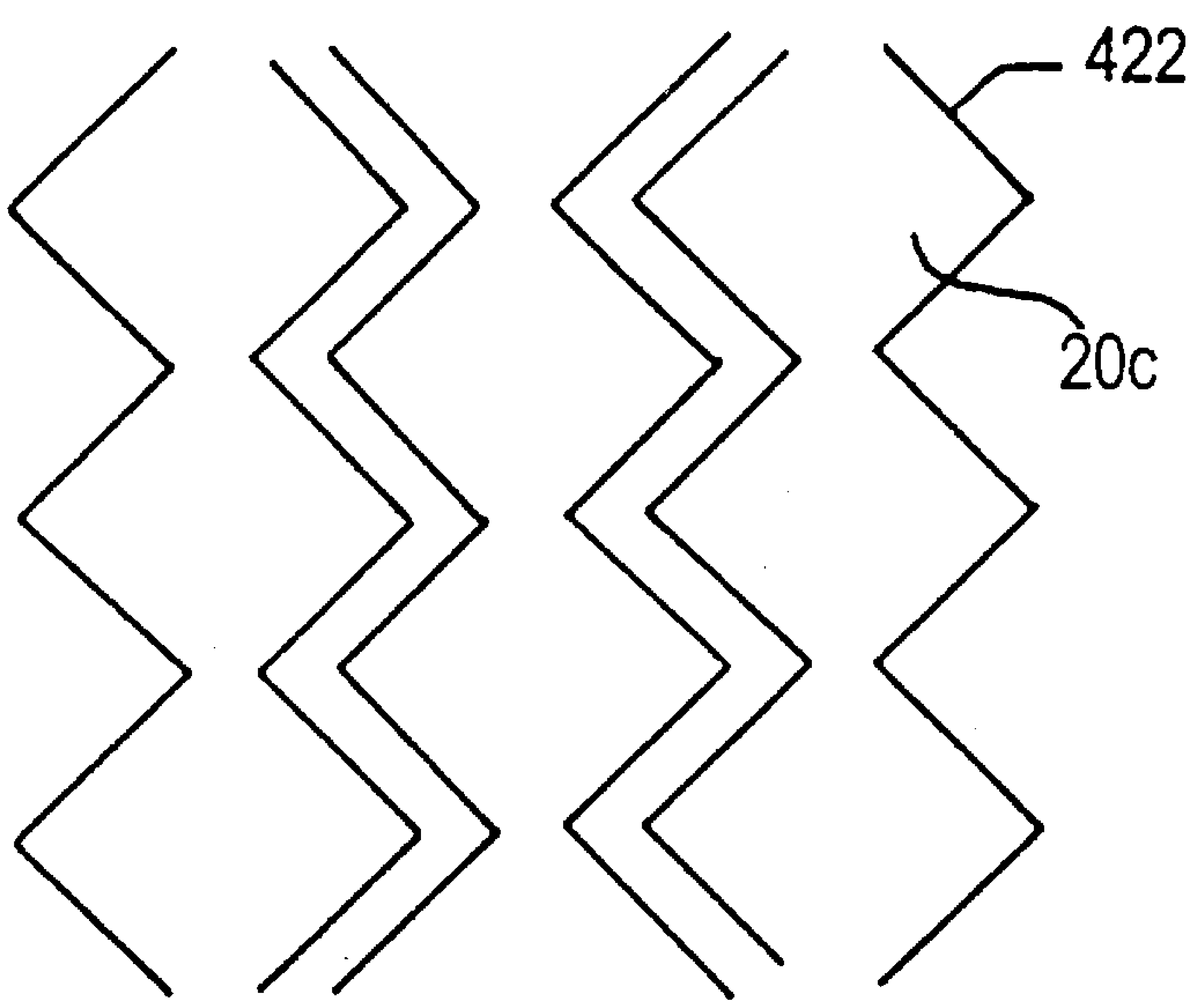


FIG. 11

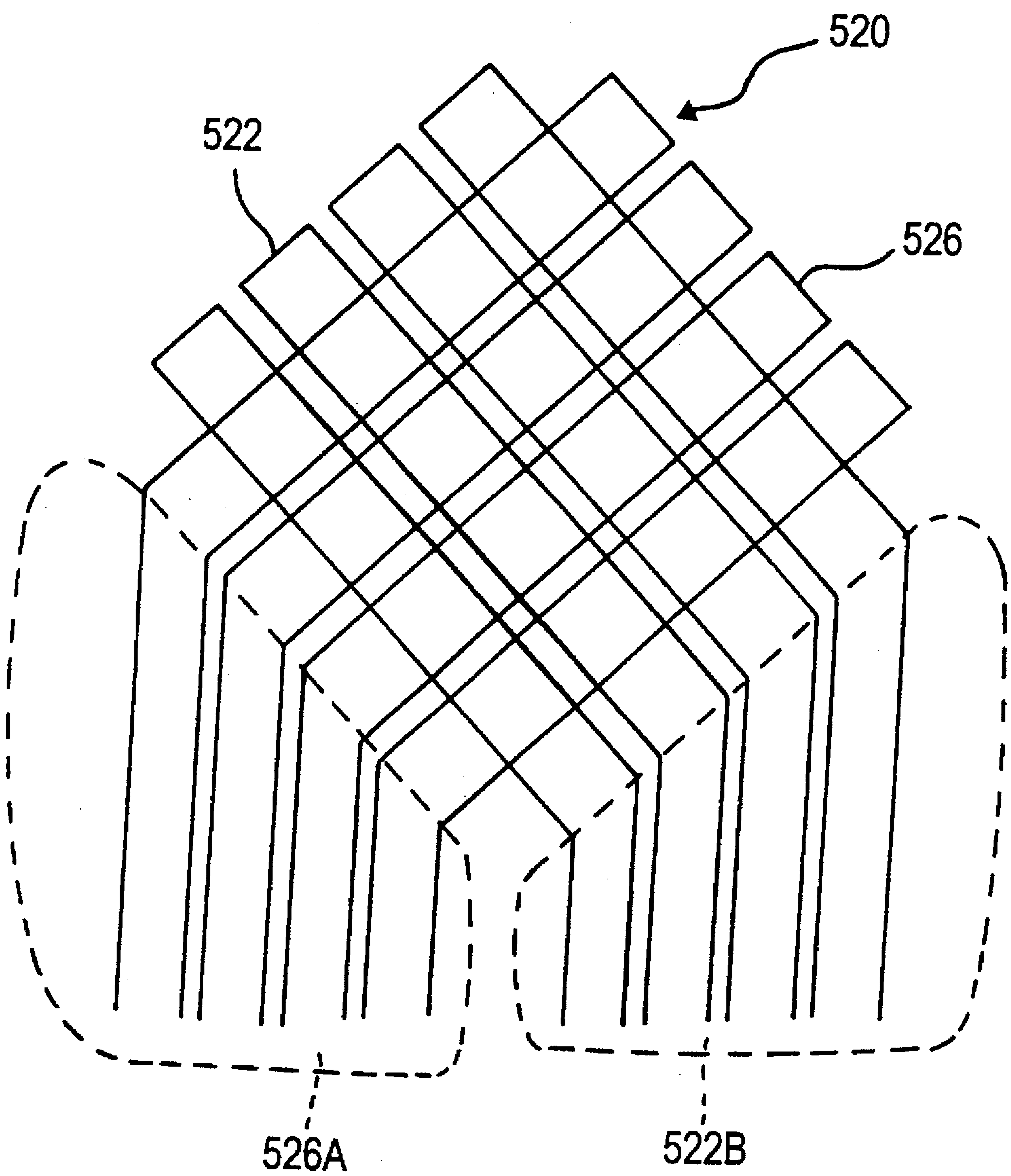


FIG. 12

FIG. 13

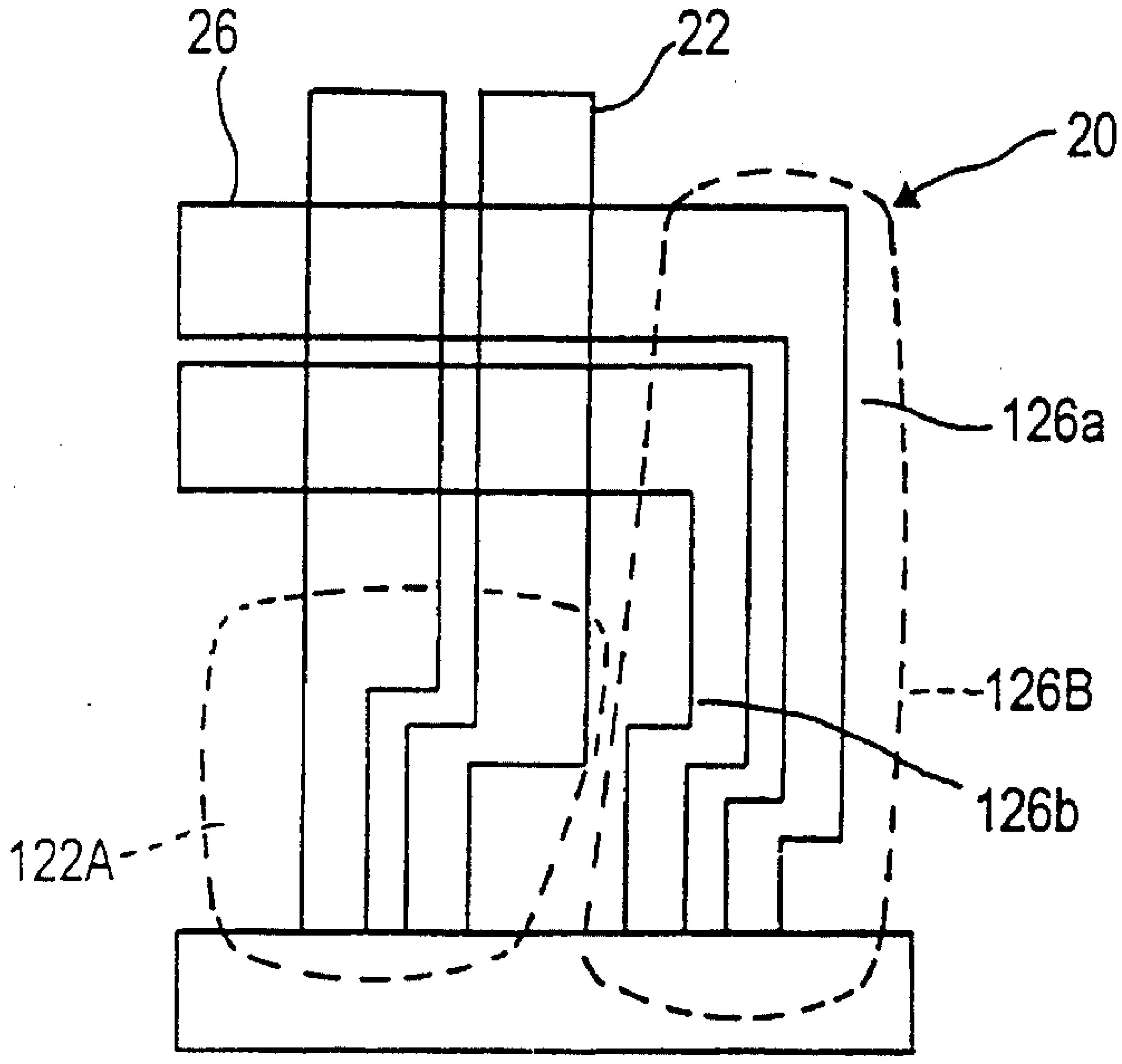


FIG. 14

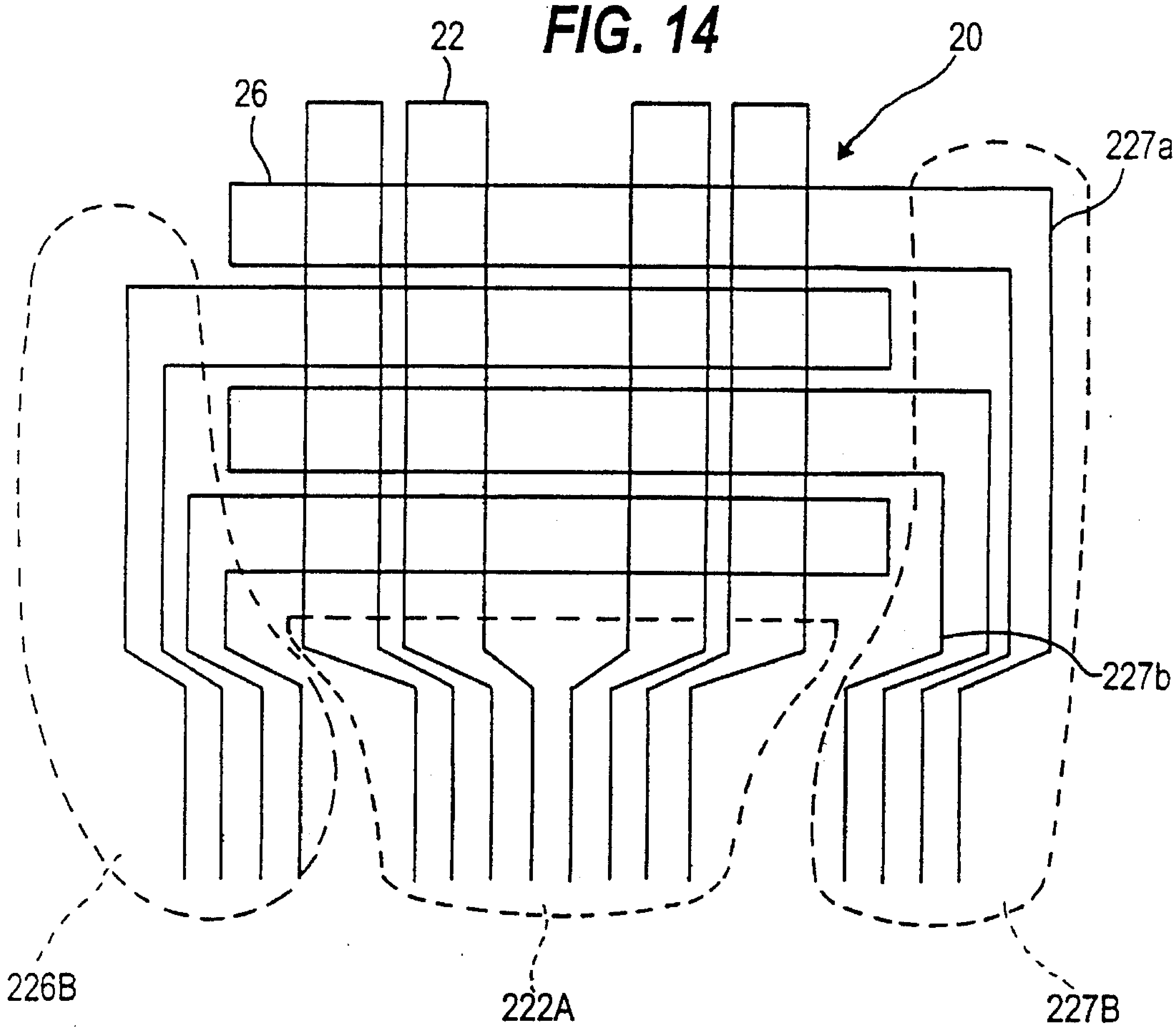


FIG. 15

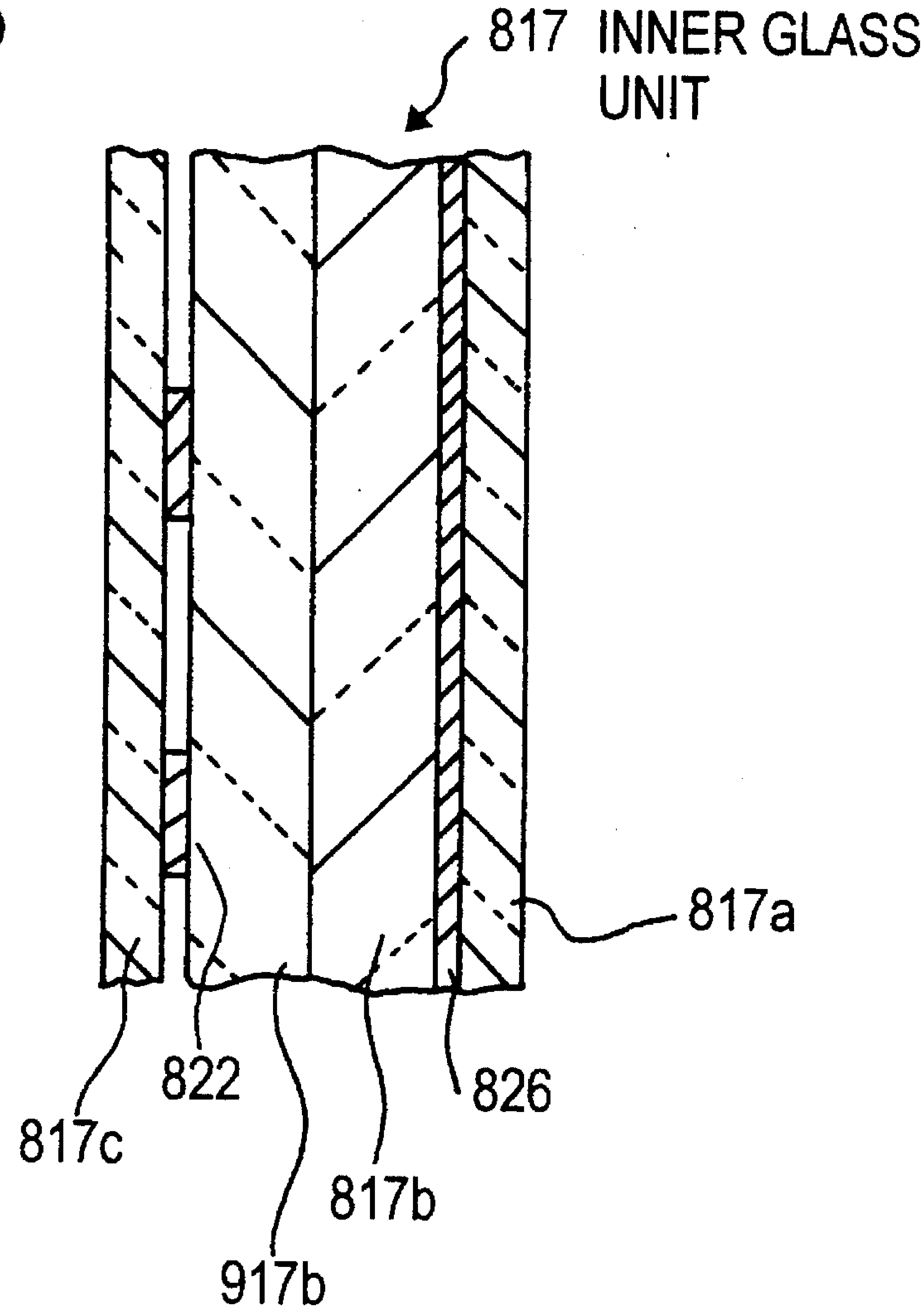
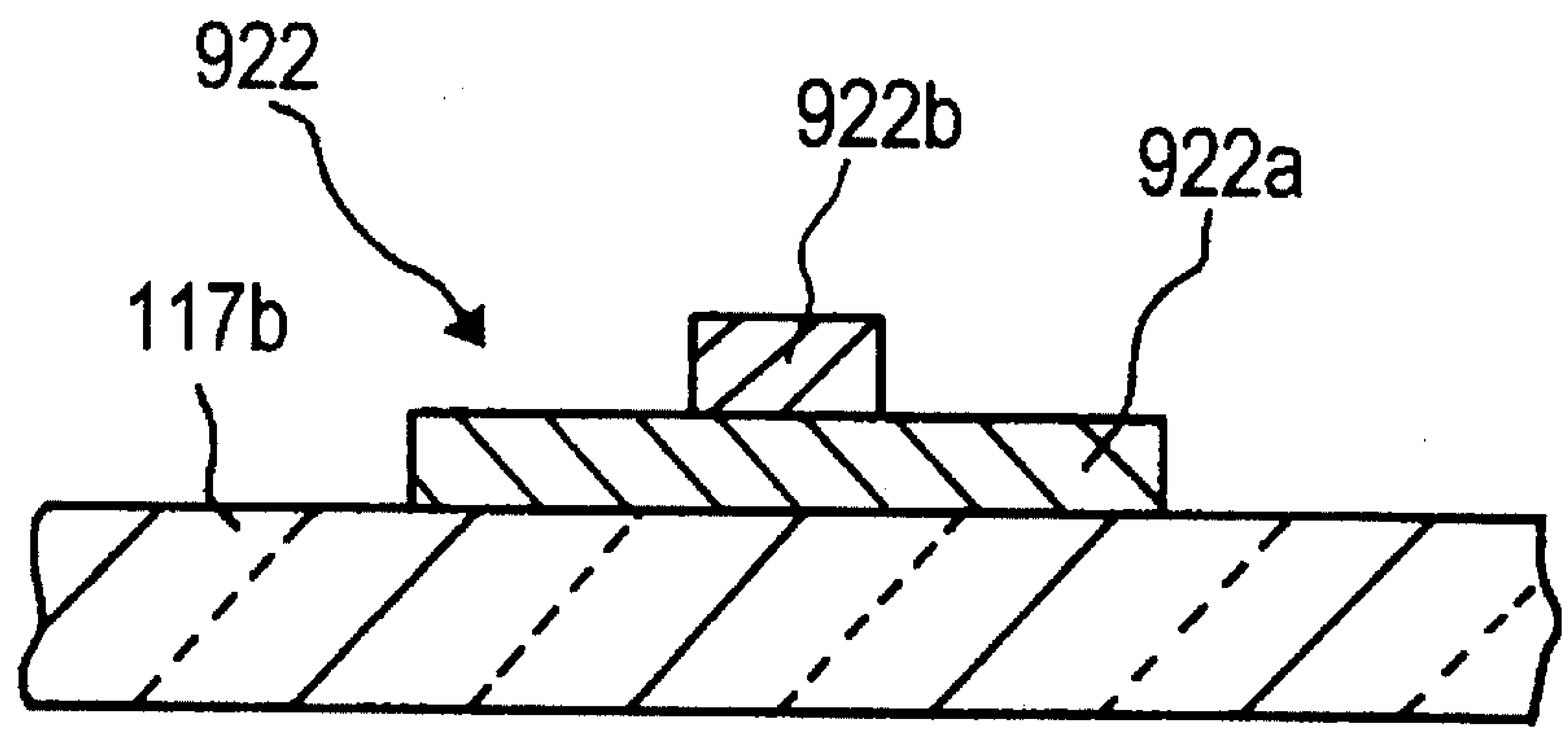

817 INNER GLASS UNIT
817a
817c
822
917b
817b
826

FIG. 16


922
922b
922a
117b

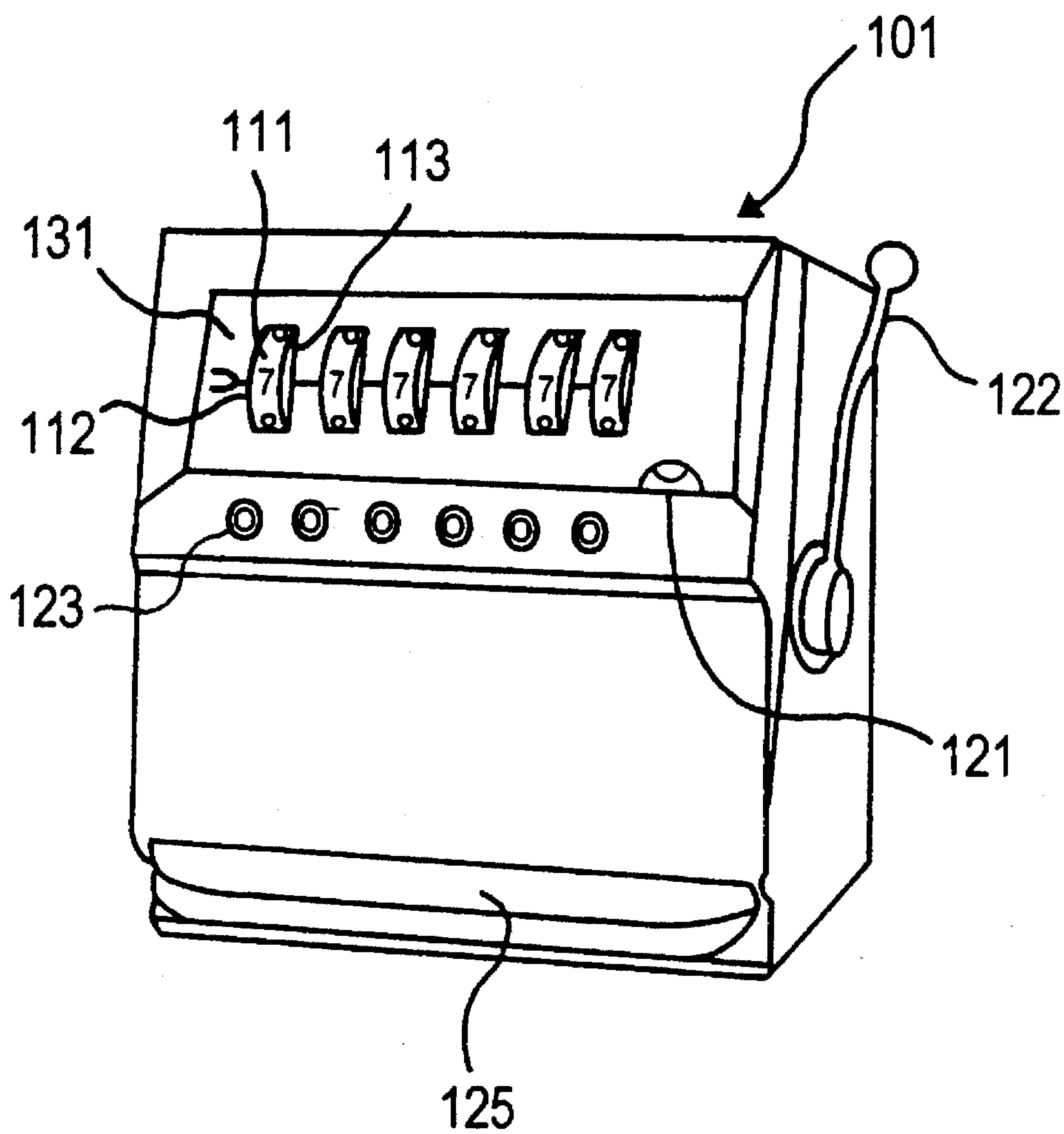


FIG. 17

SENSOR WITH A PLURALITY OF TRANSMISSION AND RECEPTION LINES FOR DETECTING A POSITION OF A METAL OBJECT

BACKGROUND OF THE INVENTION

This invention relates to a sensor for detecting the position of a metal object and in particular to a sensor appropriate for detecting the position of a metal object in a space sandwiched between parallel planes, for example.

TECHNICAL BACKGROUND

Devices requiring a sensor for detecting the position of a metal object include metal detectors, game machines, etc. For example, with some game machines, a player moves a metal object, such as a metal ball, in a specific space set within the game machine and may or may not win the play depending on the destination of the metal ball. Pinball machines are typical of such game machines; with a pinball machine, a player plays a game by dropping a pinball (a metal ball) in a space sandwiched between parallel planes in which a large number of obstacles are located.

The pinball machine has a board face for providing a space required to move pinballs, a glass plate spaced from the board face at a given interval to cover the board face, and a propelling mechanism for propelling pinballs to the top of the board face. The pinball machine is set up so that the board face becomes substantially parallel to the vertical direction. The board face is formed with a plurality of safe holes, into which the player attempts to cause a pinball to enter for a winning play (hit), in response to which the pinball is discharged from the board face, and an out hole into which pinballs not entered in the safe holes are finally collected for discharging the pinballs from the board face.

A large number of pins (nails) are set up substantially vertical to the board face in a state in which they project from the board face as far as the diameter of a pinball as obstacles with which pinballs dropping along the board face frequently collide for causing the motion direction thereof to fluctuate. The pins are located on the board face with a distribution determined so as to guide pinballs colliding with the pins toward or away from the safe holes while causing the motion directions of the pinballs to fluctuate.

Since the pinball machines have such a structure, some pinball machines may easily register hits and some may be caused to hit only with difficulty, depending on a slight difference in pin layout or inclination. Also, at a single machine, some safe holes may be high in hit average and some may be low; the hit average difference among the safe holes varies from one machine to another.

At game houses, etc., having a large number of such game machines, it is important on management such as profit management and customer management for personnel of the game house to know the characters of the respective game machines. For example, if many machines are easy to hit, the game house suffers a loss; if most machines are hard to hit, the customers lose interest in play and the game house will lose business. Therefore, personnel need to know the characters of the respective game machines installed in the house and take action accordingly.

To this end, a passage of a pinball is detected in pinball machines. As a sensor used for this purpose, a sensor provided with an upper sheet and a lower sheet forming contact pairs is disclosed in Japanese Patent Publication No. Sho 64-3506, for example. In the art described here, a pinball is placed on the upper sheet and presses it, whereby contact pairs contact in sequence as the pinball passes for detecting the of the pinball.

However, since the conventional sensor has the contact pairs, a layout of the sheets is limited; the sheets can be laid out only along passages of pinballs. Thus, the sensor cannot detect pinball motion from the viewpoint of seeing the entire board face. Thus, it is difficult for the sensor to determine how pinballs enter the save holes and the out hole.

Since a pinball is detected by physical contact of the contact pairs, pressure against the sheet may become weak depending on the pinball motion state, in which case some contact pairs cannot contact and the pinball may be unable to be detected. Also, a contact failure may occur due to abrasion, corrosion, or the like of the contact pairs. Further, the contact pairs may erroneously contact due to vibration, chattering, or the like. Thus, the sensor has a problem of lacking reliability.

Further, the sensor, which uses pressure of pinballs, also introduces a problem of delicately affecting pinball motion.

Such problems may occur on other devices as well as the pinball machines. Therefore, it is desired to work out some countermeasure.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide a sensor for detecting the position of a metal object which can detect any desired position of a metal object in a specific space without contact with the metal object and without using contacts involving physical contact, and to produce the detection result providing high reliability.

To this end, according to the invention, there is provided a sensor for detecting a position of a metal object comprising a plurality of transmission lines being energized for generating a magnetic field, a board for supporting the transmission lines, a plurality of reception lines being electromagnetically coupled with the transmission lines for detecting a magnetic flux change made by approach of the metal object, and a board for supporting the reception lines, wherein the transmission lines and the reception lines are made of conductive thin films formed on their respective boards having sending and returning paths, and are laid out in a direction to cross each other with the boards between.

The transmission lines and the reception lines can cross each other so that their cross portions are laid out like a matrix.

The areas surrounded by the sending and returning paths of the transmission lines and the reception lines in the cross portions can be made, for example, substantially quadrilaterals.

Each of the transmission lines and the reception lines can comprise two layers of a metal pattern formed on their respective boards and a metal film formed on the metal pattern as the conductive thin film. The transmission and reception lines can each comprise a transparent conductive film formed on the board and a metal film formed on the transparent conductive film as the conductive thin film. In these cases, glass boards may be used as the boards.

The direct current resistance value of each of the transmission lines and the reception lines can be set in the range of 20 to 200Ω, for example.

When an electric current flows into a turned transmission line for generating a magnetic field, an induced current is induced on the reception line near the transmission line by electromagnetic induction. At this time, if a metal object approaches the transmission line and the reception line, an eddy current is generated on the surface of the metal object in a direction to negate a magnetic flux by the transmission line. Thus, the scale of the induced current induced on the reception line is changed by the effect of the eddy current. The approach of the metal object can be detected by detecting the change.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic front view showing the form of a detection matrix used in a first embodiment of the invention;

FIG. **2** is perspective views of a game machine and the detection matrix as a conceptual exploded view;

FIG. **3** is a partial vertical sectional view of the games machine.

FIG. **4** is a front view of the detection matrix.

FIG. **5** is an enlarged sectional view of one example of a transmission or reception line used in the invention;

FIG. **6** is a block diagram showing the portion on the game machine side in one example of a signal processing system used in the invention;

FIG. **7** is a block diagram showing the main controller side in the example signal processing system used in the invention;

FIG. **8** is a schematic waveform chart showing a voltage waveform fed to transmission lines;

FIG. **9** is a schematic front view showing the form of transmission or reception lines according to a second embodiment of the invention;

FIG. **10** is a schematic front view showing the form of transmission or reception lines according to a third embodiment of the invention;

FIG. **11** is a schematic front view showing the form of transmission or reception lines according to a fourth embodiment of the invention;

FIG. **12** is a schematic front view showing the form of a detection matrix according to a fifth embodiment of the invention;

FIG. **13** is a schematic front view showing the form of a detection matrix according to a sixth embodiment of the invention;

FIG. **14** is a schematic front view showing the form of a detection matrix according to a seventh embodiment of the invention;

FIG. **15** is an enlarged sectional view of an inner glass unit having a detection matrix according to an eighth embodiment of the invention;

FIG. **16** is an enlarged sectional view of a transmission or reception line according to a ninth embodiment of the invention; and

FIG. **17** is a perspective view of a slot machine according to a tenth embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the accompanying drawings, there are shown preferred embodiments of the invention.

FIGS. **1** to **8** shows a first embodiment of the invention. In the first embodiment, a metal sensor is used as a metal detector for application to a game machine **10**.

The game machine **10** has a board face **11** for providing a space required to move metal objects B, a glass cover **10***a* spaced from the board face at a given interval to cover the board, and a propelling mechanism for propelling metal objects to the top of the board face **11**, as shown in FIGS. **2** and **3**. The game machine **10** is set up so that the board face **11** becomes substantially parallel to the vertical direction. The board face **11** of the game machine **10** is formed with a guide rail **12** for defining a game area. This means that the game area is provided inside the guide rail **12**. A large number of pins (nails) **13**, for bouncing metal objects B are hammered into the board face **11** in the game area. A plurality of safe holes **14***a*, are made at various points and one out hole **15** is made at the bottom of the game area.

The pins **13** are set up substantially vertical to the board face **11** in a state in which they project from the board face **11** as far as the diameter of the metal object B, as shown in FIG. **3**.

The pins **13** are laid out as obstacles along the course with which a metal object dropping between the pins **13** along the board face **11** frequently collides for causing the motion direction of the metal object to fluctuate. More specifically, the pins **13** are grouped into pin strings or pin groups **13***a*, as shown in FIG. **2**. The pin strings or pin groups **13***a* are located as a distribution determined so as to guide the metal objects colliding with the pins **13** toward or away from the safe holes **14***a* while causing the motion directions of the metal objects to fluctuate in response to the metal object propelling position or drop start position and the motion direction, speed, etc., of the metal object at the time.

The safe hole **14***a* is a hole into which a player trys to cause a metal object to enter for a winning play (hit) through which the metal object is discharged from the board face **11**. On the other hand, the out hole **15** is a hole into which metal objects not entering into the safe holes **14***a* are finally collected for discharging the pinballs from the board face **11**.

The front glass cover **10***a* for covering the board face **11** consists of a surface glass unit **16** and an inner glass unit **17**.

The propelling mechanism has a propelling handle **18** and a drive mechanism (not shown). The handle **18** is located on the front face of the game machine **10** for a player to propel metal objects by turning the handle **18** at any desired angle.

A ball saucer **19** for receiving metal objects paid out from the game machine **10** is also located on the front face of the game machine **10**. When a metal object projected to the top of the board face **11** falls into any safe hole **14***a*, a predetermined number of metal objects are paid out for a winning play.

A detection matrix **20** forming a metal sensor is disposed along the board face **11** of the game machine **10**, as shown in FIGS. **2** and **3**. The detection matrix **20** is built on the inside when viewed from the game machine **10**, namely, into the inner glass unit **17**, which is the side nearest the ball face **11**, of the surface glass unit **16** and the inner glass unit **17** making up the front glass cover **10***a* covering the board face **11**.

The inner glass unit **17** comprises three laminated layers of an internal protection glass plate **17***a* which is a protection sheet for reception lines **26**, a glass base board **17***b*, and an outer glass plate **17***c* which is a protection sheet for transmission lines **22**. The reception lines **26** (described below) are sandwiched between the internal protection glass plate **17***a* and the glass base board **17***b*. The transmission lines **22** (described below) are sandwiched between the glass base board **17***b* and the outer glass plate **17***c*.

A transparent conductive film **28** for shielding is provided on the full surface of the outer glass plate **17***c* on the surface of the transmission lines **22**. The transparent conductive film **28** is made of an indium tin oxide (I.T.O.) film, tin oxide film, etc.

As shown in FIG. **1**, each transmission line **22** has a parallel section **22**P comprising a sending path and a returning path in parallel and a turn section **22**T at which the sending path turns to the returning path for making a turn part (or a loop).

Each reception line **26** has a parallel section **26**P comprising a sending path and a returning path in parallel and a turn section **26**T at which the sending path turns to the returning path for making a turn part (or a loop). A plurality of the transmission lines **22** are laid out on the glass base board **17***b* so that their parallel sections **22**P are arranged within the same plane and become parallel to each other. Likewise, a plurality of the reception lines **26** are laid out on the glass base board **17***b* so that their parallel sections **26**P are arranged within the same plane and become parallel to each other. The transmission lines **22** are arranged in a row direction and the reception lines **26** are arranged in a column direction, for example, so that they cross each other to make up the detection matrix.

To form the transmission line **22**, as shown in FIG. **5**, first a film of metal such as aluminum is formed on the surface of one side of the glass base board **17***b* by means of deposition or the like for forming a transmission line pattern **22***a* like a turn. Next, on the deposition part, a film of metal such as copper is formed along the pattern by means of plating, deposition, or the like for forming a metal pattern **22***b*. Likewise, to form the reception line **26**, aluminum is deposited on the surface of the other side of the glass base board **17***b* for forming a reception line pattern like a turn on which a film of copper is formed for forming a metal pattern.

Reactivity of the transmission line **22** and/or the reception line **26** can be controlled by changing the film thickness of the copper film.

For example, if the copper film is thickened, direct current resistance of the transmission line **22** and/or reception line **26** is lowered, increasing the reactivity to metal objects.

The inner glass unit **17** comprises the internal protection glass plate **17***a* bonded to the reception lines **26** of the glass base board **17***b* and the outer glass plate **17***c* bonded to the transmission lines **22** by a transparent adhesive.

As shown in FIG. **1**, a plurality of the transmission lines **22**, each of which makes a U turn for parallel sending and returning paths, are disposed on the same plane in parallel in one direction. Likewise, a plurality of the reception lines **26**, each of which makes a U turn for parallel sending and returning paths, are disposed on the same plane in parallel in one direction.

The respective reception lines **26** are located near the respective transmission lines **22** so that they can be electromagnetically coupled. That is, the reception lines **26** are disposed in a direction to cross at right angles to the plane parallel to each transmission line **22** (that is, with the plane containing the transmission line **22** like a turn and the plane containing the reception line **26** like a turn parallel to each other) so that the electro-magnet characteristic changes as metal such as a metal object B approaches.

In the front view of the detection matrix in FIG. **1**, quadrilateral portions surrounded by the sending and returning paths of the transmission lines **22** and the reception lines **26** crossing each other provide detection units for sensing a metal object, **20***a*. The detection unit **20***a* is formed substantially like a square in the embodiment, but is not limited to the quadrilateral or square as shown in embodiments described below.

External connection terminals **23** and **27** are provided at the ends of the transmission lines **22** and the reception lines **26**. As shown in FIG. **4**, some of the detection units **20***a* correspond to the positions of the safe holes **14***a*.

The pattern forms of the transmission lines **22** and the reception lines **26** are very fine in relation with the size of a metal object B; if the detection units **20***a* are too large, resolution worsens and if they are too small, a plurality of detection units respond to one metal object, thus their positional relationship becomes hard to grasp,

Then, the DC resistance values of the transmission lines **22** and the reception lines **26** are set to preferably 10 to 200Ω or about 25Ω as the optimum value at which reactivity to metal objects B is the best.

As shown in FIG. **1**, the turn width (spacing between the sending and returning paths) of each transmission line **22**, reception line **26**, a, is set to preferably 4 to 16 mm or 8 mm as the optimum value as the width at which reactivity for detecting metal objects B is good. The width between the transmission lines **22** and between the reception lines **26**, b, is 0.5 to 2 mm or so, indicating a good result.

A pattern of the detection matrix **20** appropriate for the game machine **10** consists of, for example, 32 rows of the transmission lines **22** and 32 columns of the reception lines **26** forming 1024 detection units **20***a* in total.

The thickness of a conductor forming each of the transmission lines **22** and the reception lines **26** also has a large effect on the sensitivity. That is, if the conductor is thin, impedance is too high; if it is thick, the inner diameter of the pattern becomes small, worsening the sensitivity.

Further, the detection matrix **20**, which is contained in the inner glass unit **17** covering the board face **11**, needs to be made as thin as possible so as not to spoil the view when playing. Then, the thickness of each of the conductors forming the transmission lines **22** and the reception lines **26** is preferably set to 20 to 50 μm.

A signal processing system providing the metal detector for detecting metal objects is as shown in FIGS. **6** and **7**.

The signal processing system, which is under the control of a main controller **30**, comprises the main controller **30**, a logic controller **31** for repeating control signals, etc. from the main controller **30**, an impedance matching driver **32**, a DC offset converter **33**, a hold section **34**, and an A/D converter **35** making up a circuit system for inputting data from the detection matrix **20** to the main controller **30**, a timing generator **36**, a power supply unit **37**, and an external connection connector **38**. The logic controller **31** and the circuit system are connected to the external connection connector **38**. The main controller consists of a computer containing a central processing unit and a main memory (not shown).

Installed on the side of the game machine **10** in the signal processing system are an output system **40** for feeding power into a plurality of the transmission lines **22** of the detection matrix **20** and an input system **50** from a plurality of the reception lines **26**. The output system **40**, which is installed on the side of the transmission lines **22**, is provided with a transmission driver **41** for inputting signals to the transmission lines **22** in sequence at a predetermined period and a decoder **42** connected to the transmission driver **41** for controlling the transmission driver **41** so that it operates in sequence in response to control signals from the main controller **30**, as shown in FIG. **6**. A continuous sine wave with 0 V as the center having frequency 1 MHz is preferred, for example, as shown in FIG. **8**, as a voltage waveform **81** fed to the transmission line **22**.

Further, the output system **40** comprises a logic sequencer **43**, a timing generator **44**, and a transmission line row counter **45**.

The logic sequencer **43** operates in response to control signals from the main controller **30**; it synchronizes the decoder **42** in the transmitting system with a multiplexer **52** (described below) in the receiving system and also controls the beginning and end timings of a scanning period of signals output in sequence by the decoder **42**.

The timing generator **44** determines the scanning period, which requires a minimum of 10 KHz to cover a movement of a metal object on the board face **11** of the game machine **10**, and is set to 100 KHz in the embodiment. The transmission line row counter **45** counts the scanning period for determining the transmission line **22** to be scanned.

The input system **50**, which is installed on the side of the reception lines **26**, is provided with a converter **51** connected to the reception lines **26** for converting a current representing an electro-magnetic characteristic value of each of the reception lines **26** into a voltage signal that can be handled by digital devices at the following stages and a multiplexer **52** connected to the converter **51** for receiving signals in sequence from the reception lines **26** and outputting them.

A reception line column counter **53** located following the logic sequencer **43** of the output system **40** is connected to the multiplexer **52**. The output system **40** and the input system **50** are synchronized with each other by the transmission line row counter **45** and the reception line column counter **53** connected to the logic sequencer **43**. In one synchronization mode, for example, one of the reception lines **26** is detected per scan of the transmission lines **22**.

In contrast to the synchronization mode, for example, the reception lines **26** scan once per transmission of one of the transmission lines **22** for detection.

An output of the multiplexer **52** of the input system **50** is connected via an impedance converter **54** to the external connection connector **38** to the main controller **30**.

Next, the operation of the embodiment is described.

In FIG. **7**, when an address signal and a control signal are output from the main controller **30** via an address bus and control bus to the logic controller **31**, the logic controller **31** transfers the signals to the game machine **10** through the external connection connector **38**.

In FIG. **6**, in the game machine **10**, the logic sequencer **43** of the output system **40** issues a sequence signal based on the input signals to the decoder **42**, the timing generator **44**, the transmission line row counter **45**, and the reception line column counter **53**.

The timing generator **44** determines a scanning period of each transmission line **22** of the detection matrix **20**. The transmission line row counter **45** counts scanning period signals for determining the transmission line **22** to be driven. The counter **45** operates in synchronization with the sequence signal from the logic sequencer **43**.

The decoder **42** controls the transmission driver **41** so that the transmission driver **41** outputs a signal in sequence to the transmission lines **22** at a predetermined period.

When receiving current signals representing electro-magnetic characteristic values appearing on the reception lines **26**, the converter **51** converts the current signals into voltage signals that can be handled by digital circuitry at the following stages.

When receiving the signals into which the signals from the reception lines **26** are converted, the multiplexer **52** outputs the signals in sequence on a predetermined period. The decoder **42** in the transmitting system and the multiplexer **52** in the receiving system operate in synchronization with each other in response to the count of the transmission line row counter **45** and the count of the reception line column counter **53** operating according to control signals of the logic sequencer **43** operating according to control signals.

The logic sequencer **43** causes the converter **51** and the multiplexer **52** in the receiving system to detect information on one of the reception lines **26** per scan of the transmission lines **22** or in contrast causes the reception lines **26** to scan once per transmission of one of the transmission lines **22** for detection.

If a voltage signal having a waveform as shown in FIG. **8** is applied to one transmission line **22**, an alternating field occurs in the parallel section **22P** of the transmission line **22**, whereby an alternating voltage is induced in each reception line **26** crossing the transmission line **22** by electro-magnetic induction.

At this time, if a metal object enters a space assumed by any detection unit **20*a*** belonging to the transmission line **22**, an eddy current is induced in the metal object. The eddy current generates a magnetic field in a direction to negate a magnetic flux occurring from the parallel section **22P**. Thus, the scale of the electro-magnetic induction with respect to the reception line **26** crossing the transmission line **22** at the detection unit **20*a*** changes and induced current on the reception line **26** becomes small. On the other hand, such a change does not occur on other reception lines **26** crossing the same transmission line **22** and the scale of induced current does not change. The reception line **26** having its parallel section **26P** at the position of the metal object is scanned by the analog multiplexer **52** and the signal is finally sent to the main controller **30** for comparison. As described below, the main controller **30** can check the reception line columns for detecting a specific reception line **26** different from others in output. It can also check the transmission line rows, for example, for detecting the current transmission line **22** being driven. Therefore, the detection unit **20*a*** in which the metal object exists can be known from information on both the reception and transmission lines.

The transmission line **22** being driven can be known, for example, by obtaining the count of the transmission line row counter **45**; the reception line **26** selected by the analog multiplexer **52** can be known, for example, by obtaining the count of the reception line column counter **53**. Track of the position of the metal object can be kept as coordinates of the position at which the transmission line rows and the reception line columns cross each other.

Since the number of the detection units **20*a*** is 1024 in total, from 32 rows of the transmission lines **22** and 32 columns of the reception lines **26**, the metal object can be detected even if it passes through any of the safe holes **14** and the out hole **15**.

Since the voltage waveform **81** to the transmission line **22** is a continuous sine wave with 0 V as the center, noise, as with a square wave, does not occur and the effect on other devices such as the main controller **30** can be prevented.

A sensor signal output from the multiplexer **52** is impedance-converted by the impedance converter **54**. The resultant sensor signal output from the impedance converter **54** is input through the external connection connector **38** to the impedance matching driver **32** on the side of the main controller **30** for impedance matching. The DC offset converter **33** following the impedance matching driver **32** receives only a reaction wave of output from the detection matrix **20** and outputs it to the hold section **34**.

The hold section **34** temporarily stores data transferred at high speed until the A/D converter **35** at the following stage completes A/D conversion. The A/D converter **35** converts analog signals from the detection matrix **20** into digital signals in predetermined bit units, such as 12 bits, and sends the resultant digital data via a data bus to the main controller **30**. The operation of the hold section **34** is synchronized with that of the A/D converter **35** in response to a signal of the logic controller **31** or the timing generator **36**.

The A/D converter **35** may be provided with another output terminal connected to the memory (not shown) for storing motion of all metal objects on the detection matrix **20** for a long time.

Since the detection matrix **20** consists of the transmission lines **22** and the reception lines **26** which make U turns in parallel and are at right angles to each other, its pattern is simple and unobtrusive and can be easily manufactured with wire such as copper wire. If the line diameter of each of the transmission lines **22** and the reception lines **26** of the detection matrix **20** is made 20 μm or more, DC resistance lowers for providing good reactivity.

The transparent conductive film **28** on the surface of the outer glass unit **17***c* has functions of shielding electric effects of metal and inductors from the outside and of raising reactivity to metal objects.

The positions of the detection units **20***a* corresponding to the safe holes **14***a* are stored and further the position of the out hole **15** is also stored (without detecting metal objects at the out hole **15**, the number of metal objects propelled to the board face **11** can be counted as the number of incoming balls) for watching how metal objects enter the holes during the progress of games. Locking up the game machine on a win is possible and a check is made for an error caused by illegal operation according to the situation. Machines where metal objects very easily enter only specific safe holes, machines where metal objects hardly enter safe holes, etc., are detected for use as data to adjust a fluctuation amount imparted to metal objects by pins, etc.

Next, a second embodiment of the invention will be discussed.

FIG. **9** shows the form of transmission or reception lines according to the second embodiment of the invention. That is, the transmission lines (or reception lines) **222** are bent like a zigzag. The second embodiment is the same as the first embodiment except for the form of the transmission or reception lines.

Next, a third embodiment of the invention will be discussed.

FIG. **10** shows the form of transmission or reception lines according to the third embodiment of the invention. That is, the transmission line (or reception line) **322** has the form swollen like a circle in the portion of a detection unit **20***b*. The third embodiment is also the same as the first embodiment except for the form of the transmission or reception lines.

Next, a fourth embodiment of the invention will be discussed.

FIG. **11** shows the form of transmission or reception lines according to the fourth embodiment of the invention. That is, the transmission line (or reception line) **422** is bent like a zigzag and has the form swollen like a square in the portion of a detection unit **20***c* and the zigzag form is engaged with that of its adjacent transmission or reception line. The fourth embodiment is also the same as the first embodiment except for the form of the transmission or reception lines.

As shown in the second to fourth embodiments, the transmission or reception lines can have various forms according to applications, purposes, etc. The transmission and reception lines may be of different line forms in combination.

Next, a fifth embodiment of the invention will be discussed.

FIG. **12** shows the form of a detection matrix according to the fifth embodiment of the invention. That is, a plurality of transmission lines **522** and a plurality of reception lines **526** are introduced from the same direction (in the FIG. **12**, from bottom to top) and bent and extended at an angle of 45 degrees in directions to cross each other for forming a layout of a detection matrix **520**. The fifth embodiment is the same as the first embodiment except for the form of the detection matrix.

Next, the operation will be described.

The fifth embodiment is designed so that an area **526**A and an area **522**B become substantially the same in pattern length, as shown in FIG. **12**. Thus, the transmission lines **522** and the reception lines **526** differ less in total length. Therefore, as compared with the first embodiment, the transmission lines **522** and the reception lines **526** are substantially the same in DC resistance value and DC resistance can be easily averaged on the transmission lines **522** and the reception lines **526**; as a result, reactivity can be averaged.

In the examples given above, the transmission lines **522** and the reception lines **526** are substantially the same in DC resistance value. However, they may differ in DC resistance value depending on applications, purposes, etc., as is the case with the sixth and seventh embodiments of the invention.

FIG. **13** shows the form of a detection matrix according to a sixth embodiment of the invention. The sixth embodiment is the same as the first embodiment except for the form of the detection matrix.

In the sixth embodiment, an area **122**A and an area **126**B differ extremely in pattern length. Further, in the area **126**B, a line portion **126***a* and a line portion **126***b* differ in pattern length. Thus, the transmission lines **22** and reception lines **26** have different DC resistance values.

FIG. **14** shows the form of a detection matrix according to a seventh embodiment of the invention. The seventh embodiment is the same as the first embodiment except for the form of the detection matrix.

In the seventh embodiment, an area **222**A, an area **226**B, and an area **227**B also differ in pattern length. In the area **227**B, a line portion **227***a* and a line portion **227***b* differ in pattern length. Thus, the transmission lines **22** and reception lines **26** differ in DC resistance value.

Thus, the detection matrix can have various forms according to applications, purposes, etc.

Next, an eighth embodiment of the invention will be discussed.

FIG. **15** shows the structure of an inner glass unit having a detection matrix according to the eighth embodiment. That is, the inner glass unit **817** comprises four layers of an internal protection glass plate **817***a*, a reception glass base board **817***b*, a transmission glass base board **917***b*, and an outer glass plate **817***c*, which are laminated on each other. A plurality of reception lines **826** turned in parallel are formed on one side of the reception glass base board **817***b*, on which the internal protection glass plate **817***a* is put.

A plurality of transmission lines **822** turned in parallel are formed on one side of the transmission glass base board

917*b*, on which the outer glass plate **817***c* is put. Then, the inner glass unit **817** is manufactured by putting the board face of the reception glass base board **817***b* and the board face of the transmission glass base board **917***b* together using a transparent adhesive. Others are the same as the first embodiment.

The inner glass unit **817** is thus manufactured by putting the two glass base boards **817***b* and **917***b* together to make it easy to manufacture the inner glass unit **817**.

In the embodiment, two glass base boards **817***b* and **917***b* may be made one glass base board having both sides undergoing pattern treatment for forming the turned transmission lines **822** and the turned reception lines **826**.

Pattern treatment may also be applied to the internal protection glass plate **817***a* and the outer glass plate **817***c*.

The glass base boards **817***b* and **917***b* may be made of plastic films as well as glass.

Next, a ninth embodiment of the invention will be described.

FIG. **16** shows a transmission or reception line according to the ninth embodiment. That is, to form the transmission line **922**, a transparent conductive pattern **922***a* of an I.T.O film is formed on one surface of a glass base board **117***b*, on which a film of a metal pattern **922***b* is formed by depositing, plating, or the like of metal such as copper along the transparent conductive pattern.

The I.T.O. film can be formed by thin film techniques such as sputtering, for example. Likewise, to form the reception line, a transparent conductive pattern of an I.T.O film is formed on the other surface of the glass base board **117***b*, on which a film of copper is formed.

According to such a structure, if the copper pattern of the transmission line **922** or reception line is broken, the transparent conductive pattern under the copper pattern is still connected, thereby preventing the transmission or reception line pattern from being broken.

Copper foil may be applied by a conductive adhesive rather than forming a copper film on the I.T.O. film.

In the embodiments, the game machine has been discussed, but use of the detection matrix is not limited to the game machine. For example, the detection matrix can be used to detect a distribution, movement, etc., of metal objects. To use the detection matrix for detecting a distribution of metal objects, for example, if a metal piece of a specific pattern is attached to each commodity and the commodities are placed on the detection matrix, the presence or absence of the commodities can be detected. Therefore, it can be used for inventory management of the commodities. By attaching similar metal pieces to articles, the detection matrix can also be used for quantity control. In addition, it can be applied to a detector for counting and examining metal objects at prize exchange places, etc.

Next, a tenth embodiment of the invention will be described.

FIG. **17** shows a slot machine according to the tenth embodiment of the invention. That is, at the slot machine **101**, a plurality of common displays **112** are provided on the outer peripheral surfaces of six rotators **111**. A player starts playing a game by inserting a medal into a medal slot **121** and pulling a handle **122** toward them. Then, the rotators **111** rotate at high speed and the player stops the rotators **111** in sequence by pressing stop buttons **123** corresponding thereto in sequence.

Any one of the displays on each rotator **111** is positioned on a display window **113** for each game. When all displays **112** positioned on the display windows **113** provide a predetermined win display, such as "7," a predetermined number of medals, for example, are paid out to the player through a win slot **125** for the winning play.

Each rotator **111** is made of a belt or sheet of a nonconductor such as plastic or rubber and is rotated by two belt pulleys (not shown). Each rotator **111** is positioned with metal such as iron (not shown) attached to the position of a predetermined win display, such as "7." The display windows **113** are covered with a front glass cover **131** which has a similar structure to that of the inner glass unit **17** in the first embodiment (see FIG. **3**). The front glass cover **131** is formed with a detection matrix **20** providing a metal sensor. The detection matrix **20** serves as a metal detector for detecting metal as in the first embodiment and will not be discussed again.

Next, the operation will be described.

When the rotators **111** stop, if all of the displays positioned on the display windows **113** provide a predetermined win display, such as "7," the condition is detected by the detection matrix **20**. An internal CPU, such as the main controller **30** as shown in FIG. **7**, is informed of the positions of metal sensed by the detection matrix **20**. When the CPU acknowledges that the displays provide a predetermined win display, a predetermined number of medals, for example, are paid out to the player through the win slot **125** for the winning play accordingly.

The detection matrix **20** may be installed in the slot machine **101** as well as formed on the display windows **113** on the front of the slot machine **101**. To detect the metal positions, the start positions of the rotators **111** are checked by the detection matrix **20** and then the metal positions may be detected by the internal CPU.

As in the first embodiment, the front glass cover **131** in the tenth embodiment may consist of a surface glass unit **16** and an inner glass unit **17**.

In the embodiments, for example, the detection matrix can provide a metal form determination device for determining the metal form like a printed wiring board or an indication position detection sensor such as a touch sensor. For example, when the metal wiring portion of a printed wiring board is placed on the detection matrix, the metal form determination device can detect the position of metal. When an indication member having at least a metal object on the tip is used and the tip is made to approach any position on the detection matrix, the indication position detection sensor detects the indication position by the detection matrix.

If the density of the detection matrix is made appropriate, metal objects can be traced and games can also be monitored in detail. The detection matrix may be disposed on the rear of the board face of the game machine.

The conductors forming the transmission lines **22** and the reception lines **26** may be metal such as aluminum or gold as well as copper or transparent conductive films such as indium oxide films or tin oxide films.

In the embodiments described above, each sensor comprises a detection matrix, which has a plurality of transmission lines and reception lines, but may have a simple structure of one transmission line and one reception line.

As described above, according to the embodiments of the invention, any desired position of a metal object existing in a specific space can be detected in a noncontact condition without involving physical contacts. Therefore, according to the invention, problems involved in presence of contacts, etc., are solved and durability and reliability can be improved in detection of metal objects.

Particularly, the invention is appropriate for detection of the position of a metal object moving or being still within a parallel plane space. For example, with a game machine, data such as trace of metal objects on the board face, the number of metal objects propelled by a player, and percentage of metal objects entering safe holes can be obtained easily and quickly and games can be known in detail at a distant location, thus the level of count control of game machines can be raised and nails of game machines can be easily adjusted by anybody.

A distribution of metal objects on a plane can also be easily detected.

The invention can be applied to various devices if they are devices for detecting the position of a metal object existing in a specific space. For example, it can be applied to detection of the path of a metal object at a game machine where a player moves metal objects along the board face. When metal objects are placed on the detection matrix according to the invention, a position distribution of the metal objects can be detected. A device for recognizing the metal object form by using the presence distribution of the metal objects can be constructed. A system for managing articles by using information on the presence distribution of the metal objects can be built. Further, a sensor for entering indication, etc., by making a metal object approach a desired position on the detection matrix according to the invention can be constructed.

We claim:

1. A sensor for detecting a position of a metal object comprising a plurality of transmission lines being energized for generating a magnetic field, a board for supporting said transmission lines, a plurality of reception lines being electro-magnetically coupled with said transmission lines for detecting a magnetic flux change made by an approach of the metal object, and a board for supporting said reception lines,

wherein said transmission lines and said reception lines are made of conductive thin films formed on their respective boards, each transmission and reception line having sending and returning paths, the sending path being coupled to and substantially in parallel with the returning path, said transmission lines and said reception lines being spaced apart by said boards and being laid out in a direction to cross each other.

2. A sensor as claimed in claim 1 wherein said transmission lines and said reception lines cross each other so that their cross portions are laid out like a matrix.

3. A sensor as claimed in claim 2 wherein areas surrounded by the sending and returning paths of said transmission lines and said reception lines in the cross portions are substantially quadrilaterals.

4. A sensor as claimed in claim 2 wherein said transmission lines and said reception lines each comprise a layer of a metal pattern formed on each of the boards, and a metal film formed on said metal pattern, said metal pattern and said metal film constituting said conductive thin film.

5. A sensor as claimed in claim 4 wherein said boards are glass boards.

6. A sensor as claimed in claim 4 wherein a direct current resistance value of each of said transmission lines and said reception lines is set in the range of 20Ω to 200Ω.

7. A sensor as claimed in claim 2 wherein said board on which said transmission lines are formed and said board on which said reception lines are formed have their sides on which a conductive thin film is not formed put together.

8. A sensor as claimed in claim 2 wherein said board on which said transmission lines are formed and said board on which said reception lines are formed are the same, said board having one side formed with the transmission lines and the other side formed with the reception lines.

9. A sensor as claimed in claim 2 wherein said transmission and reception lines each comprises a transparent conductive film formed on said board and a metal film formed on the transparent conductive film as the conductive thin film.

10. A sensor as claimed in claim 9 wherein said boards are glass boards.

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